

D180-18424-1

UTILIZATION SURVEY OF PROTOTYPE  
STRUCTURAL TEST ARTICLE

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FINAL REPORT

CONTRACT NO. NAS 8-30621

OCTOBER 14, 1974

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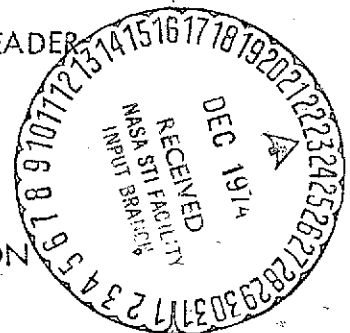
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FOREWARD

This document contains the Boeing Aerospace Company's final report on the Utilizational Survey of Prototype Structural Test Article Study conducted under National Aeronautics and Space Administration Marshall Space Flight Center Contract No. NAS 8-30621. The period of performance was May 1, 1974, through November 30, 1974. The work was performed under the technical direction of Mr. J. Herring NASA/MSFC.

The purpose of the contracted study was to survey the Aerospace and Aircraft Industry to determine the latest procedures and practices in utilizing prototype test articles in operational flight systems.

Boeing personnel who performed this study include S. Baber, Program Manager; H. M. McDaniel and M. J. Berry, Principal Investigators.

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## SUMMARY

A survey of six aerospace companies and two NASA agencies was made to determine how prototype structural test articles are used in flight operations. Prototypes are flight-like structures used for testing and are generally not flown. Results of the survey indicate:

- (A) Prototype test articles are not being discarded after development testing is complete. Some uses found were:

- Test Fixtures for appendages
- Mockup for crew training
- Test Bed for evaluating design changes
- Refurbished for flight or flight backup
- Planned protoflight vehicle

- (B) Only two cases of prototypes being refurbished and flown were identified.
- (C) Protective devices and inspection techniques are available to prevent or minimize test article damage.
- (D) Substitute programs for design verification are available in lieu of using prototype structural test articles.
- (E) There is a trend away from dedicated test articles.

Four options based on these study results were identified to reduce test and hardware costs without compromising reliability of the flight program. These are alternates to the standard prototype approach.

(1) PROTOTYPE DELETION

The dedicated prototype structural test article can be deleted under circumstances where design confidence exists or when design verification can be performed later on flight structure.

(2) EXPENDABLE MODEL

Rather than an expensive flight type configuration prototype, consider a simple expendable structure when design confidence does not exist.

(3) MULTI-USE PROTOTYPE

Determine early in the design phase whether the prototype should fly or be put to other uses, and implement configuration controls as required.

(4) PROTOFLIGHT VEHICLE

For one of a kind spacecraft use the protoflight approach and fly the prototype structure.

- Verify analyses with modal surveys
- Add flight subsystems and conduct reduced level or duration qualification
- Fly without additional environmental acceptance

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## 1.0 INTRODUCTION

### 1.1 BACKGROUND

One expensive area in new space vehicle programs is the development of static and dynamic test articles. In many cases these test articles are identical to actual flight hardware in design, material, fabrication and workmanship. Discarding these articles after structural testing is completed, appears wasteful. Utilization of the test article in operational flight systems could result in tremendous savings by decreasing the number of flight systems produced.

### 1.2 OBJECTIVE AND SCOPE

This study was initiated in May, 1974 to determine how structural test articles are used in flight programs with the objective of recommending test program guidelines. The study was limited to two man-months of effort. Hence, selectivity had to be exercised in the areas that could adequately be covered. Accordingly, the study was conducted according to a four point plan:

- (1) Develop a survey checklist.
- (2) Survey industry test practices.
- (3) Evaluate and compile the survey data.
- (4) Develop and document guidelines.

### 1.3 APPROACH TO THE SURVEY

A review of Boeing experience was made for spacecraft, boosters and aircraft structural development programs. A comprehensive survey list was developed from this initial data and reviewed with MSFC.

A survey of industry was accomplished in two trips with stops at MSFC to review preliminary results. The first trip included Lockheed, Hughes, JPL and TRW. The second trip was to McDonnell-Douglas, Martin-Marietta, and GSFC.

The data was evaluated and conclusions were drawn. Recommended guidelines for future structural test programs were determined. These recommendations are expected to reduce test costs in addition to test article acquisition and tracking costs.

## 2.0 SURVEY

### 2.1 SURVEY QUESTIONS

Interviews were held with test representatives of six aerospace companies and two NASA agencies. Each representative was asked to provide answers to nine standard questions. These questions were designed to reveal specific as well as general philosophical information relative to structural test article histories and trends toward flying such articles.

- (1) Do you ever program structural test on flight hardware?  
What type of articles and what program?
- (2) What type of inspections or status checks do you perform to determine refurbishment requirements prior to flying a test article?
- (3) If you have flown prototype structural test articles, what were the critical design factors? I.E. load limited? Frequency limited?
- (4) What other recommendations would you give toward the use of prototype structural test articles in flight program?
- (5) How would you modify a test program to insure that a prototype structural test article would be acceptable for flight? What tests would be deleted?
- (6) What type of protective devices and test instrumentation do you use to minimize structural damage during the test series?
- (7) What test approaches or analytical alternatives do you use in planning a prototype structural test program?
- (8) If you use prototype test articles for flight, what testing compromises such as computer analyses are used? Identify the types of analyses.
- (9) What uses do you make of prototype structural test articles before and after the test series?

The answers to these questions as provided by the test representatives are enclosed as the Appendix to this report.

## 2.2 SURVEY LIMITATION

No attempt was made to interview only structural test requirements personnel. The participants were from various organizations with differing interests. They represent a cross-section of test oriented people in industry. They included structural designers, test planners, dynamicists, test program managers, test conductors, department heads, and test specification writers.

The views of those interviewed are strictly their own and may not coincide with policies of their respective companies or departments.

## 2.3 SURVEY PARTICIPANTS

Table 1 lists the test participants, the company or agency they represent, and the programs discussed.

CONTRACTOR/AGENCY	REPRESENTATIVES	PROGRAMS
Boeing Aerospace Company Kent, Washington	Wes Martin - Project Structures Manager Paul Stern - Structures & Dynamics Staff Bill Armstrong - Huntsville Structures Staff Olaf Olson - System Test Staff	SOFT (Signature of Fragmented Tanks)  MVM 73 (Mariner 10)  Burner II STP 68-1 (Space Test Program) STP 70-1 STP 72-1 S3 Satellites
Lockheed Missile & Space Company Sunnyvale, California	Jack Williamson - Structures Staff Bob Hill - Trident Test Board Barney Morais - Space Test Board	Trident ATA-6
Jet Propulsion Laboratory Pasadena, California	George Milder - Structural Test Robert Freeland - Structures & Dynamics Technical Staff	Viking Mariners
TRW Systems Redondo Beach, California	John Otera - Manager Environmental Test	HEAO SATCOM
Hughes El Segundo, California	Robert Zuziak - Structures & Dynamics Technical Staff	Air Force Satellites Commercial Satellites
McDonnell-Douglas Huntington Beach, California	Russ Brown - Chief Structures Design Bob Murray - Chief Structures Analysis	Skylab Delta Boosters
Martin-Marietta Denver, Colorado	Don Trent - Test Planning Staff Jim Parham - Structures Staff	ATM (Apollo Telescope Mount) MOL-HSW (Manned Orbiting Laboratory) Skylab
Goddard Space Flight Center Marland	Brian Keegan - Applied Dynamics Staff	OAQ (Orbiting Astronautical Observatory) OSO (Orbiting Solar Observatory)

TABLE 1

## INTERVIEW PARTICIPANTS

### 3.0 DISCUSSION OF RESULTS

#### 3.1 GENERAL

The results of the survey provide the basis for generalized recommendations which may not apply in their entirety to every test program but should be useful during the planning phase of every test program.

Success requires the establishment of a policy of testing that is based upon individual program needs rather than tradition. Several contacts on the survey felt that many tests are run to satisfy vague implied requirements rather than specific program objectives. It is important that the test requirements reflect the mission objectives, design concerns and laboratory capabilities.

#### 3.2 DISPOSITION OF TEST ARTICLE

Test articles are not generally being discarded after structural testing. However, it is evident that planned future uses of prototypes should be developed early in any program. Some uses found in the survey are:

- (1) Use the structure as a fixture for testing appendages and other mating structures - Boeing and McDonnell-Douglas.
- (2) Use the prototype as a mockup for crew training - Martin-Marietta and McDonnell-Douglas.
- (3) Refurbish the structure and fly it - Lockheed and GSFC.
- (4) Use the structure for tests to evaluate running changes in design in a series of spacecraft - JPL and GSFC.
- (5) Use the prototype as a backup to the flight unit - Boeing.
- (6) Plan to fly the prototype and implement controls to insure the article remains flight quality - Lockheed and Boeing

#### 3.3 DAMAGE AND REFURBISHMENT

Only two cases were found where a prototype test article was refurbished and flown. One was a large booster adapter skirt at Lockheed. The skirt was static tested without failure. Refurbishment details were not available but effort was minimal. The second case was at GSFC. An OAO vehicle failed in flight. A prototype was upgraded to flight configuration and launched to replace the failed unit.

In general, protective devices are available to prevent damage to flight hardware during test and these same devices are used on prototypes. One of the best descriptions of the devices required is provided in JPL 900-434, "Standard Testing Facilities and Practices".

Inspection techniques are available to reveal structural testing damage. Techniques found being used include acoustic emission, laser holography, vibration frequency signature, optical methods, physical visual check, performance tests, tooling checks, die penetrant and others.

### 3.4 SUBSTITUTE PROGRAMS

There are substitute programs available in lieu of using a prototype structural test article. These include:

- (1) Conservative design - Both Boeing and McDonnell-Douglas have a no test concept which requires design factors of 1.8 to 2.0 times expected loads.
- (2) Analyses - All companies use a finite element analyses such as NASTRAN and SAMAS, or simplified versions. Good correlation is being attained with test results.
- (3) Expendable model - Hughes uses low cost models that only simulate basic structure to verify analyses.
- (4) Other alternates - Results indicate many designs are stiffness or envelope limited. In many cases load capability is such that static testing is not required.

### 3.5 PROTOFLIGHT VARIATIONS

The protoflight concept is being endorsed by a large portion of the Aerospace Industry. GSFC has promoted the concept which is described in its Document S-320G-1 "General Environmental Test Specification for Spacecraft and Components". Essentially, the protoflight is a qualification vehicle used for flight. Detailed descriptions of acceptable development, qualification, and acceptance testing variations are available in the NASA SP-8000 series documents referenced at the end of this report.

GSFC has used the protoflight concept on most of its programs during the past four years. Boeing has gone one step further by programming the protoflight vehicle structure for development testing also. This technique has been successfully used on Burner IIA upper and lower stages, and heat shields, and on STP 68-1, 70-1 and P72-1 satellites, heat shields and stages.

#### 4.0 RECOMMENDATIONS AND GUIDELINES

Four recommendations based on these study results were selected to significantly reduce test and hardware costs without compromising reliability of the flight vehicle. These guidelines are given in subsequent paragraphs.

##### 4.1 PROTOTYPE DELETION

The dedicated prototype structural test article can be deleted under circumstances where design confidence exists or when design verification can be performed later on flight structure. Design confidence can be obtained by:

- (1) Design of the structure to allow a large margin of safety.
- (2) Similarity of design to previous successful spacecraft.
- (3) Past success in correlating the math model to test results.

##### 4.2 EXPENDABLE MODEL

Rather than an expensive flight type configuration prototype, consider a crude expendable structure. This should be done if:

- (1) An early verification of math models is required or desired.
- (2) Tests of flight hardware structure occur too late in the program to allow recovery if design changes may result.

##### 4.3 MULTI-USE PROTOTYPE

Program the prototype structural test article for flight or other future use. Potential uses are crew training mockups, test fixtures for flight vehicle appendages or mating structures, test vehicle to solve problems during future missions, test beds for evaluating running changes in a series of spacecraft, or flight vehicles. The following steps should be implemented:

- (1) Determine early in the design phase what the uses will be.
- (2) Institute the required configuration and material controls to support the future uses.
- (3) Select test levels that do not jeopardize the planned future uses.
- (4) Use frequent inspections.

##### 4.4 PROTOFLIGHT VEHICLE

The protoflight vehicle concept can produce the most economical test program. The protoflight vehicle concept is ideal for one of a kind spacecraft. Qualification is performed on the flight unit, saving the cost of a separate vehicle for design verification. It can be used in any program along with one of the three previous recommendations. Consider the following program:

4.4

PROTOFLIGHT VEHICLE, continued

- (1) Verify the math model through a modal survey of the protoflight structure.
- (2) Add flight subsystems and conduct a design verification or qualification test series at reduced levels or durations.
- (3) Fly the vehicle without additional environmental acceptance tests.

## 5.0 REFERENCES

- NASA SP-8043 Design-Development Testing  
May, 1970 (NASA Space Vehicle Design Criteria Monograph)
- NASA SP-8044 Qualification Testing  
May, 1970 (NASA Space Vehicle Design Criteria Monograph)
- NASA SP-8045 Acceptance Testing  
April, 1970 (NASA Space Vehicle Design Criteria Monograph)
- LMSC D154085 Space Systems Division  
Baseline Test Program for Flight Systems  
January, 1973 (LMSC)
- MIL-STD-1540A Test Requirements for Space Vehicles (USAF)  
April, 1974
- S320G-1 General Environmental Test Specification for Spacecraft  
and Components  
May, 1973 Rev. (NASA GSFC)
- JPL 900-434 Standard Environmental Testing Facilities and Practices  
April, 1971 (JPL)
- D5-17269 Criteria for Structural Test Final Report NAS8-29070  
August, 1973 (Boeing)

INTERVIEW DATA

APPENDIX

TO

UTILIZATIONAL SURVEY OF PROTOTYPE

STRUCTURAL TEST ARTICLE

CODE

BAC	BOEING AEROSPACE COMPANY
SOFT	SIGNATURE OF FRAGMENTED TANKS
SSPS	SPACE SUPPORT AND PROPULSION SYSTEMS
MVM	MARINER VENUS MERCURY
IMSC	LOCKHEED MISSILE AND SPACE COMPANY
JPL	JET PROPULSION LABORATORY
TRW	TRW SYSTEMS GROUP
HAC	HUGHES AEROSPACE COMPANY
MDAC	MCDONNELL-DOUGLAS ASTRONAUTICS COMPANY
MMC	MARTIN-MARIETTA COMPANY
GSFC	GODDARD SPACE FLIGHT CENTER

- (1) DO YOU EVER PROGRAM STRUCTURAL TESTS ON FLIGHT HARDWARE? WHAT TYPE OF ARTICLES AND WHAT PROGRAM?

BAC

SOFT Yes. Vibration testing on component and system level.

SSPS Yes. Always on one of a kind S/C & Burner II stages. Resonant search, static proof, deployment, acoustic, and pyroshock.

The following were refurbished test articles that were flown:

Burner IIA	Upper and Lower stages
Burner IIA	Heat Shield
STP P72-1	Satellite (Air Force)
S3 Satellite	(not flown yet)
STP 68-1	Satellite
STP 68-1	Satellite Heat Shield
STP 70-1	Satellite
STP 70-1	Stage

MVM Yes. The MVM 73-1 was a refurbished test unit that would have been flown if the primary flight unit MVM 73-2, would have encountered problems.

LMSC

For the Trident missile the development models are not close to flight configuration. This is a large program with over 500 flight missiles and 5 to 6 missiles are for ground test with another 30 for flight test. Some major structural sections of flight configuration are tested to ultimate failure.

A large (107 dia. X 460 long) spacecraft fairing and adapter skirt was tested to 110% of design and there was a fairing failure. This was refurbished and tested again to 125% of design. There were no dynamic tests. They also went through 2 pyro shocks. The booster adapter skirt was refurbished and flew. The fairing did not.

JPL

No load tests are normally done on flight structure. Load limitations are established in structural design criteria. Prototypes are structurally tested. Some flight hardware should not be subjected to static test. Vidicon tubes or honeycomb structure where you could not visually locate failure are examples.

The trend is to eliminate static tests on flight articles. Use modal survey and sine vibration.

TRW

We are working on the HEAO satellite for MSFC (Ron Jewel). There are 3 spacecraft which will fly. Structural/Dynamic testing will be performed on one spacecraft. Static tests will be run on another flight model, up to 125% of the expected flight load.

HAC

Static testing is always done on an X-1 model. This is primary structure and not a prototype.

MDAC

We run limit load tests on a number of launch vehicle fairings that fly. Sometimes a single loading above limit is used to seat the joints and increase fatigue life. This slightly yields some of the material. We also run separation tests on fairings. A contained explosive shears the rivets for separation. These articles are later refurbished and have flown on Delta, Titan and Saturn vehicles. We also proof test tanks to 10 - 15 percent above limit.

MMC

In general we do not run structural tests on flight hardware. On ATM, we did run static tests on non-primary flight structure.

The MOL HSQ was a one only vehicle made from an old Titan 3C tank with new design fore and aft skirt structures. The tank which had been damaged in the factory was refurbished. The new structure had a safety factor of 2 and was proofed to 1 1/4 and flew.

GSFC

We run acceleration and dynamic tests on flight hardware - no static tests.

(2) WHAT TYPE OF INSPECTIONS OR STATUS CHECKS DO YOU PERFORM TO DETERMINE RE-FURBISHMENT REQUIREMENTS PRIOR TO FLYING A TEST ARTICLE?

BAC

SOFT Post Test Performance Tests and Physical Checks.

SSPS Visual damage inspection. C/O with tooling or dimensional check to verify no permanent deformation. Verify no functional degradation of mechanisms. Verify all critical alignments.

MVM Following structural model static test, vibration test and temperature control test, a partial disassembly was made. Quality assurance inspection of critical parts was conducted.

LMSC

After structural test most missiles could not be repaired for flight. Part of the major structure is graphite epoxy. For flight acceptance this structure is taken to 60% of ultimate. Acoustic emission is being used with a mapping technique to locate flaws. Also laser holography.

Inspection/stress data for the adapter skirt is available and will be provided to you later.

JPL

For basic structure system level damage can be located by a low level modal before and after structural/dynamic testing. Isolate one or 2 modes from 10 to 50 Hz. We have found solar panel damage in this manner when a frequency shift occurred. We do not use holosonics or acoustic emission.

TRW

We do not use acoustic emission. More data is needed to get some quantitative results. We have used holographics. We use lasers for pre and post dimensional checks. There is a visual inspection and bolt torques are checked.

HAC

A physical check is made plus a short random burst signature test. These signatures can be used to determine damage through frequency shifts.

MDAC

We use visual inspections, die penetrant/structural loading, etc. Isolator strips around bay electronics periferies are structurally loaded. If the adhesive bonding holds, they are flown. We have also used acoustic shear wave techniques to find cracks in large forged beams. We have not used low level vibration.

MMC

We use visual and die penetrant. On some small in-house programs we have used stress coat. We have not used acoustic emission as Rockwell has.

GSFC

We use visual inspection. We also run low level sinusoidal sweeps before and after dynamic tests to locate any changes in structural response.

(3) IF YOU HAVE FLOWN PROTOTYPE STRUCTURAL TEST ARTICLES, WHAT WERE THE CRITICAL DESIGN FACTORS? I.E. LOAD LIMITED? FREQUENCY LIMITED?

BAC

SOFT Envelope limited.

SSPS Mostly stiffness critical items. Normally, no static load test if safety factor can be 20 with negligible weight penalty.

MVM Load limited.

LMSC We have not flown prototype missiles.

JPL I believe Viking is our first S/C which is load limited. Previous spacecraft were limited in other factors. On MM71 acceleration levels were limited. Some members were limited to given resonant frequencies.

Viking is designed for transient load where the Mariners used a conservative sinusoidal approach.

TRW Our spacecraft appear to be over-designed for static load.

HAC Most spacecraft are limited in fundamental frequency. We do not want large responses in the 17-23 Hz area. Envelopes have to be met. In general they over design for load.

MDAC We have not flown any complete prototype test articles, except fairings. The design critical factor is load.

MMC We do not fly prototypes but our general experience is that very few design considerations give a high safety factor, except load.

GSFC We do not have a design criteria document. Most design load factors are for steady state loads. Frequency constraints are not placed on payload designers.

(4) WHAT OTHER RECOMMENDATIONS WOULD YOU GIVE TOWARD THE USE OF PROTOTYPE STRUCTURAL TEST ARTICLES IN FLIGHT PROGRAMS?

BAC

- SOFT Run vibration sweeps up to flight levels. Conduct vibration surveys with simulators and real equipment.
- SSPS Strive for simplicity of test. Simplify test and minimize instrumentation, improve costs and schedules.
- MVM Need good relationship between requirements, design and test organizations to assure realistic test requirements.
- Consider using some test articles for spares to avoid fabrication of spares.

LMSC

We don't think its feasible to fly prototypes where large quantities of missiles are involved.

The SSD test council is kicking around designing to higher levels and minimizing structural tests. The protoflight concept is being promoted at Lockheed.

JPL

We would minimize testing

- a) Design with higher factor
- b) Use less fatigue sensitive materials
- c) Use dampers on appendages
- d) Use instruments during test to limit loads

JPL now designs with a 1.25 factor.

TRW

I recommend the protoflight concept. Especially for a flight spare. The qualification tested black boxes could be used on this frame.

HAC

We are starting to get into the protoflight mode using levels of 1.2 times expected. We use durations between acceptance and qualification.

We find in general that our commercial contracts are short. They use extra articles for test. The government contracts are longer and are for fewer vehicles requiring lots of additional analysis. I don't know if the analysis cost is worth the saving.

MDAC

We would still want to run some static tests. We do use a no-test factor where we overdesign with a 1 1/2 factor on top of the 1 1/4 normal factor for a 1.87. We always run modal surveys and on Skylab we used dummy masses on a structure to get multiplication factors. McDonnell-Douglas does not have a baseline test document.

MMC

We would design to a high factor, and probable screen the test article for flaws that might precipitate crack growth.

GSFC

On OAO (Orbiting Astronomical Observatory), there was a failure in flight of an early vehicle. The structural model was upgraded, qualification tested, refurbished, acceptance tested, and successfully flown.

In general, GSFC wants a backup primary structure, and have had no programs without one. On OSO (Orbiting Solar Observatory) only one flight vehicle will be built. We will do a vibration test to protoflight levels, with no static or centrifuge tests.

- (5) HOW WOULD YOU MODIFY A TEST PROGRAM TO INSURE THAT A PROTOTYPE STRUCTURAL TEST ARTICLE WOULD BE ACCEPTABLE FOR FLIGHT? WHAT TESTS WOULD BE DELETED?

BAC

SOFT Lots of analytical & development testing, minimal system (environmental) testing. Vibration survey, no static.

SSPS Already doing this on Burner II and STP satellites. Delete sine and random sweeps on total spacecraft, except low level resonant search. Run sweeps at component level.

MVM No deletions. Go to greater lengths to establish realistic test levels.

Test at highest level of assembly possible. This will improve test realism and save money.

LMSC

We never upgrade test missiles for flight. Prototype vulnerability tests are run to select between alternate designs. We even destroy some of our flight configuration test missiles because a major concern is self-destruct capability.

We have a prototype antenna on the ATS-6 built on a subcontract to Fairchild. See June 10, 1974 Aviation Week. The Fairchild ATS-6 satellite is almost all protoflight. They should be contacted.

JPL

We do not do structural tests on flight hardware except for proof loading tanks. If structural tests were done on a flight model, it would be strain gaged to limit induced loads on members below anticipated flight loads. We would use the math model. On Viking the structural test verified the math model (SAMAS).

TRW

Conducting modal surveys are necessary to verify the math model. Design margins are sufficient to take static loads. Static tests should be eliminated on a protoflight although maybe some development tests should be run.

Thermal testing and acoustic testing are worthwhile.

HAC

Static tests should be eliminated for redundant load path structures. More extensive modeling would be required. I don't know if the extra analysis is worth the saving of an extra primary structure. Also the spacecraft will be heavier, which is alright only if you have the launch capability.

MDAC

We would instrument the test article to prevent localized overloads. We have a new mini-computer controlled structural test capability, not part of the data acquisition system. The computer will control hydraulic cylinder loads through a 50 channel capability. Actual loads are compared to predicted loads and reduced or slow dumped if required.

MMC

We do not have a baseline test plan. Each program has its own requirements. We would have to look at each test article in detail.

GSFC

We would recommend that structural tests not exceed protoflight levels.

(6) WHAT TYPE OF PROTECTIVE DEVICES AND TEST INSTRUMENTATION DO YOU USE TO MINIMIZE STRUCTURAL DAMAGE DURING THE TEST SERIES?

BAC

SOFT Accelerometer. Analyze low level data before full level test.

SSPS Accelerometers for shutdown to avoid excessive loads.

Nets to catch parts in separation tests.

Train technicians to understand that everything is flight hardware.

Test in clean facilities.

MVM

Accelerometers, strain gages, EDIs. Analyze low level data before full level test. Run modal survey to improve confidence in analysis, then locations of instrumentation can be selected better.

Had experience where strain gage may have saved test article from overtest.

LMSC

Use strain gages on visual display. Also use deflectometers.

JPL

We use many protective devices as specified in Document JPL 900-434. These include protection on:

Armature current  
power amplifier input  
servo input  
overturning moment  
vibrator overtravel  
switching sequence on peak limiter

We also use strain gages and accelerometers on the hardware.

TRW

Data acquisition is automated so that there are real time load-deflection curves on an X-Y plotter. Raw data is multiplexed and converted to engineering units. Special groupings of data can be selected for digital television display.

HAC

We use strain gages and accelerometers. On some panels we use stress coat, but this would be hard to remove from flight hardware.

MDAC

We would use strain gages and deflectometers in addition to the computer controlled loading.

MNC

We use strain gages on visual display. Our equipment is not automated, so we rely on people to monitor and control our static tests.

GSFC

We preset acceleration levels for dynamic tests. We also monitor strain levels.

Our vibrators have armature current limit shutdown and loss of servo feedback automatic shutdown. We cannot rapidly shut down our centrifuge.

(7) WHAT TEST APPROACHES OR ANALYTICAL ALTERNATIVES DO YOU USE IN PLANNING A PROTOTYPE STRUCTURAL TEST PROGRAM?

BAC

SSPS Additional independant analysis to improve confidence in design. Some additional analysis costs result. Protoflight concept functions to shorten schedule by deleting dedicated test hardware and shortening test program. Added analysis is parallel effort.

LMSC

Enclosed is a chart of our Trident test program from pre-prototype through production.

Our spacecraft approach is defined in our test baseline document, and is similar to the new MIL Std. 1540.

JPL

I would do design verification as follows:

- a) high level modal survey
- b) static test
- c) prevent otest with limiting devices

We used a NASTRAN structural analysis for Mariner Jupiter Saturn. SAMAS was used on Viking. Math models are only good in the low frequency range.

At JPL qualification and acceptance tests are checks that the assembly is put together correctly - not design verification.

TRW

We use the NASTRAN analysis on some programs. Our structural test programs are similar to industry. We have good correlation between test and math models.

HAC

On our AF contracts we run a modal survey and acoustic tests. We run sine and random vibration on our commercial contracts only. Structural tests are confined to primary structure, not prototypes. We get very good correlation to in-house math models (not NASTRAN).

MDAC

We do not have a standard test baseline. The NASTRAN analysis is used and we run both static tests and modal surveys.

MMC

In general, we run modal surveys and static tests on primary structure. We have used NASTRAN only for buckling or plastic deformation. We have in-house finite element programs for dynamic and static tests.

GSFC

We would run modal, vibration, acceleration, acoustics and pyro shock. We do not see acoustic testing replacing random vibration. We use NASTRAN models to predict subsystem response. We use a simple model with 5 - 10 elements for system loads.

- (8) IF YOU USE PROTOTYPE TEST ARTICLES FOR FLIGHT, WHAT TESTING COMPROMISES SUCH AS COMPUTER ANALYSES ARE USED? IDENTIFY THE TYPES OF ANALYSES.

BAC

SOFT The qualification unit will be the flight unit. Emphasized analysis and development work to minimize testing.

SSPS Math models are being improved to allow reduction in testing.

MVM Math models are improving in general. Probably could do less testing than we did on MVM 73. Appendages make analysis difficult in some cases. Probably will always need some testing. The problem lies in devising good tests. Airplanes provide an example for the need for testing. We have been analyzing aircraft performance for many years, and have good math models but haven't eliminated the need for some testing.

Flight transducers are useful since they can give us real flight data that can be used in future analytical work.

LMSC

The Trident program has a large number of missiles. Prototypes are never upgraded for flight.

I am only aware of the ATS-6 antenna that flew on a satellite.

JPL

I am aware of no programs where prototype hardware has flown, except possibly busses or small assemblies. These would have flown on follow-on programs to the one for which they were designed.

The knowledge of the launch vehicle environment is important. After one mission, subsequent missions rely heavily on analysis.

TRW

On the HEAO's we are not even running a modal survey. The vehicle weighs 7000-8000 pounds.

HAC

We use lower levels and shorter durations than for qualification.

MDAC

We have not flown prototype test articles.

MMC

We have not flown test articles except for the MOL HSQ. This was overdesigned to a factor of 2.

GSFC

We would use the protoflight concept.

(9) WHAT USES DO YOU MAKE OF PROTOTYPE STRUCTURAL TEST ARTICLES BEFORE AND AFTER THE TEST SERIES?

BAC

SOFT Prototype becomes flight unit.

SSPS Verify fixture, handling procedures, mockup for wiring bundles, thermal blankets, envelopes, interfaces, etc. Occasionally used for test bed for engineering evaluation of deployed mechanisms, ejection mechanisms, etc.

MVM Prototype was used for development test, qual test, scheduled to fly as backup unit to MVM 73-2. Occasionally prototype was used as test bed for deployment tests.

LMSC On the Trident program there were 4 prototype missiles. There is one for a handling interface hangar queen, one electrical hangar queen, one static load missile and one for a dynamic survey and underwater launch.

Spacecraft structural test articles are used (as in the case of the fairing) for interface tests, and as a test bed for modal tests. We do not test to destruction on structural test articles.

JPL Prototype hardware is used for fixture certification as well as for mechanical and electrical interface tests.

TRW On fleet Satcom a development model was turned into a thermal model and then a hangar queen used for checkout of modifications during the program.

HAC We do not run structural tests on prototypes.

MDAC In many cases we use prototype structural test articles for fixtures. This is especially true with fairings. On Skylab we delivered the prototype to NASA for a crew training mockup.

MMC We use prototypes for mockups, displays, and for downstream testing if problems occur with flight units. On the MOL HSQ we used a qual. Titan 3C skirt as a loading fixture. On Skylab we delivered the Multiple Docking Adapter test unit to Houston for a crew mockup.

GSFC Sometimes prototypes are upgraded to newer designs and are used for tests of subsequent missions. GSFC is looking at the concept of a common carrier vehicle for many future missions. Many prototype structures have seen 10 to 15 vibration tests.